The Fruit Tree Red Spider (Metatetranychus ulmi Koch, Tetranychidae, Acari) and its relation to its host plant

by

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Contents

1. Introduction

The influence of environmental factors on the Fruit Tree Red Spider (*Metatetranychus ulmi* Koch) has been studied by many authors. Climate, predators and spray chemicals have been the main points for consideration but the influence of food does not seem to have received its due share of attention.

In the following I propose to consider some details of this factor. A general review of the investigations into the biology and control of this mite has been published in Dutch (with a very short English summary (Kuenen 1946)). Certain aspects of special interest will be treated more extensively in separate articles. The first of these was on the influence of predators (Kuenen, 1947) ; others will follow later.

2. The damage to the leaf

Anyone acquainted with fruitgrowing is familiar with the bronzing of the leaves of plum and apple trees caused by the feeding of the Fruit Tree Red Spider. There seems, however, to be some misunderstanding regarding its origin and location in the leaf.

The mites live on both the upper and lower surface of the leaf. They can puncture the epidermis with their stilets which penetrate into the parenchyma. The cell-contents is ingested and when the mites are well fed the contents of the intestinal tract is dark green.

The cells on the lower side (spongy parenchyma), when depleted by feeding, do not acquire the brown colour. The palissade cells,

however, become distinctly brown when their contents has served as food for the mite. Isolated cells do not show up, except under the microscope, but when about one fourth of the cells are brown, the colour change becomes obvious in the field.

The discoloration of the cells of the upper layer of the palissade parenchyma is the only visible damage done by the mite (fig. 1). The lower surface may seem brown but that is only the case in transmitted light. Exceptionally, very young leaves, when heavily attacked, may show a slight bronzing of the spongy parenchyma. White spots (groups of entirely depleted cells of the palissade parenchyma) are due to other animals, mainly Jassids. Other species of Tetranychidae may cause certain brown areas on the lower surface (*Tetranychus urticae* Koch).

Secondary necrosis can appear in deeper layers of the parenchyma and the epidermis over the damaged cells later dies and collapses (fig. 1). In the final stage the whole leaf can die and then it is shed.

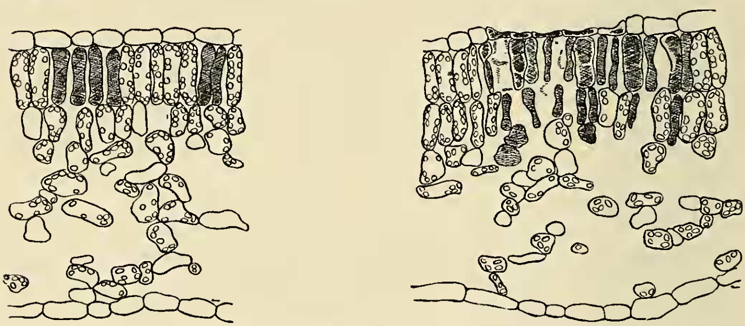

Fig. 1. Cross section through the leaf of an apple. To the left: recent attack by *M. ulmi*; a few cells of the upper layer of the palissade parenchym have turned brown. To the right: older damage with secundary necrosis.

As the stilets cannot reach far into the leaf, the visible damage of the leaf must be due to mites feeding on the upper surface of the leaf. This is remarkable in view of the fact that the mites are most generally found on the lower side of the leaf. It is well known that the mites migrate to the upper surface only on warm, and preferably sunny days. Consequently a tree may harbour an abundance of mites without showing any discoloration of the leaves of importance, as long as the weather remains cool. As soon as the temperature rises the mites attack the upper surface in great numbers and may produce the brown discoloration in a few days.

The reason why the mites migrate to the upper surface in warm weather only will be discussed later (p. 100).

3. Overcrowding.

In 1941 countings of mites were made on two trees of the variety Perzikrode Zomerappel throughout the summer and the results are given in figs. 2 and 3.

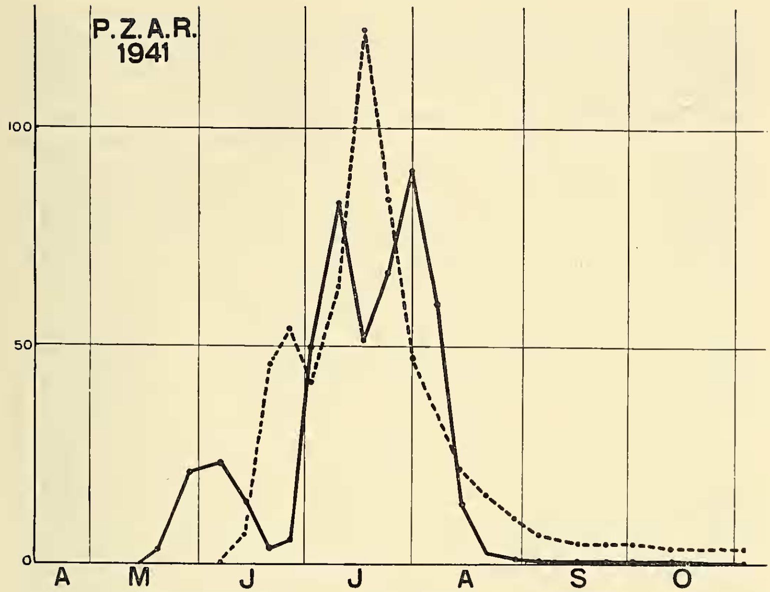

Fig. 2. Population fluctuations of mites (full line) and eggs (broken line). Abscis : months April (A) to October (O). Ordinate : mean number of individuals per leaf, from 100 leaves. P.Z.A.R. : var. Perzikrode Zomerappel, tree "R".

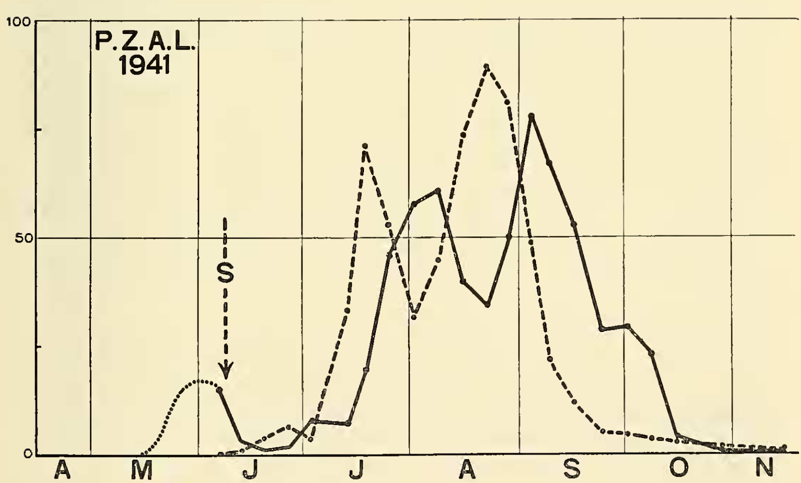

Fig. 3. Idem as fig. 2. P.Z.A.L. : var. Perzikrode Zomerappel, tree "L". S : moment of application of a wash of lime-sulphur 3/4 %.

Every week a sample of 100 leaves was taken from each tree and the numbers of mites and eggs were counted. As calculation showed, 50 leaves gave results which were considerably less accurate, while taking 200 leaves did not increase the accuracy more than a few percent which was not worth while.

Samples were taken carefully "at random" (small and large leaves, from centre and periphery of the tree, from high and low and from long and short shoots). By the heavy toll taken weekly the total number of leaves might have been reduced seriously. Therefore the actual number of leaves on the tree were counted, the results of which are given in table 1.

Table 1. Numbers of leaves on two experimental trees, 1941

tree	long shoots	short shoots	total
P. Z. A., R.	1993	19552	21545
id. L.	1242	14181	15423

The total number of leaves picked during the summer (ca. 2400) apparently was not very large compared with the total number present on the trees.

This work was mainly done during the war when we had not yet learned of the method designed by Austin & Massee (1947) to estimate the numbers of mites. As, for other reasons, we wanted the results immediately and as we counted predators at the same time, this method would not have been particularly convenient and we have since continued to do it in the old way. *)

In general the following can be said about the graphs. The graphs begin in the spring with the increase of the number of mites from zero upwards. These are the mites which emerge from the winter eggs and migrate to the leaves. In many cases this part of the curve is more or less S-shaped thus showing the rate of emergence from the winter eggs. The total period of emergence is about 3 weeks. Most of the mites, however, appear in the second week. When the first maximum of the curve has been reached the egg line begins. Before that moment it was always seen that full grown adults were on the leaves. The emergence of the winter eggs takes about as long as the development of the first-hatched larvae to adults. When therefore the adult females begin to deposit the summer eggs the increase of mites through emergence from winter eggs has stopped. The mite-graph then declines owing to the death of a number of mites.

In the mean time the egg-graph increases quickly and reaches a maximum, just about when the mite-graph reaches its minimum. This then is the moment when the hatching of the summer eggs becomes faster than the deposition of new eggs (by the last remaining females). At the same time the increase of young larvae becomes greater than the death of the adults.

*) Since we have a refrigerator at the laboratory the samples of leaves can be stored easily for at least 24 hours which makes work much easier.

In this way the different generations succeed one another. The most remarkable fact is that the different generations can be followed up to the end of the year. This is entirely contrary to the general expectation. (M a s s e e, 1929; G e ij s k e s 1938, etc.). Only G i l l i a t (1935a) remarks that the generations can be distinguished throughout the year.

During the countings it was found that the distribution over the age-groups was different at the different points of the graphs, the number of adults increasing when a maximum in the mite-graph is reached, the numbe of young larvae being largest at a minimum of the graph. Single determinations, however, are not sufficient to decide in what stage of development the generation is.

L i s t o c.s. (1939) made counts on leaves with the aim of determining the number of generations. The number of leaves per determination was much smaller, but the number of determinations larger. The generations do not show very well in their graphs, but in conjunction with other observations their conclusions seem reliable, namely that there are 2 to 5 generations per year, dependant upon circumstances.

About the relative and absolute height of the maxima the following can be remarked. A maximum in the egg-graphs is composed by all the eggs present at that moment. As the development of the egg takes 8—10 days there will be 8—10 day-classes of eggs present. A maximum of mites, however, is composed from about 20—25 day-classes as the development from larva to adult plus the mean time of life of the adults is about 3 weeks. If the number of individuals in a population were constant for some period, the maxima in the mite-graph would still be more than twice as high as the maxima in the egg-graph. While, therefore, the maxima of the mite-graph are mutually comparable, and also the maxima of the egg-graph, we must bear in mind that the relative height of the two graphs is not directly comparable.

The graphs end with a mite maximum. The following egg maximum is missing as the eggs are then deposited on the branches and they are not counted there. The decrease in the egg-graph is thus caused by the hatching of the summer eggs, while the decrease of the mite-graphs has its origin in the migration of the adult females to the branches of the tree (and, of course, death of all stages on the leaves).

There is an abrupt end to the graphs. There are always a few mites left on the leaves when they are shed in the autumn, besides a number of winter eggs which have been deposited on the leaves "by mistake". The counts were discontinued when the greater part of the leaves had fallen.

There is a remarkable difference in the number of generations on the two trees of Perzikrode Zomerappel, the one having three the other four. The first generations are about parallel. After the application of lime-sulphur on the tree L. at S., we see a marked reduction in the numbers of mites. As we know, the eggs are not killed by this wash. After some time the population recovers. After

the 3rd generation no more summer eggs are deposited on the tree R., while on tree L. the development continues. At that time tree R. showed very severe bronzing of the leaves as a result of the mite attack, while tree L. was still practically green.

Something similar was also found on other varieties and in other years.

Not only these and other regular countings, but also isolated observations clearly showed that when the leaves of a tree show bronzing caused by heavy mite attack, they apparently can no longer supply sufficient food — or the right kind of food — for the mites. As a result the females migrate to the branches and start depositing winter eggs. The number of winter eggs deposited is small relative to the size of the mite population.

Cottier (1934) remarked that after the bronzing of the leaves had taken place, no more winter eggs were deposited, and that summer eggs were only produced as long as the leaves remained green. Geijskes (1938) is of the opinion that scarcity of food stimulates the production of winter eggs.

Apparently then not only the climate, but also food supply can limit the number of generations. As a rule the level of overpopulation is not reached on the tree and the leaves remain green until normal climatic shedding begins.

It should be noted that this conclusion has an important bearing on the control of the mite. Spraying after the leaves have turned brown has no great effect, as the mites then abandon the leaves anyway.

This also explains the apparent anomality often observed by the fruitgrowers that after a year of severe attack there are few winter eggs while after a year with little Red Spider damage large amounts of eggs may be found on the branches.

If the population is high there will be severe bronzing of the leaves and premature egg-deposition resulting in a small number of winter eggs. If the population is kept at medium height either by climatic influences (low temperatures reducing the rate of development, and rain reducing the numbers of mites present), or by spraying, the mites can develop until the end of the season and will produce a very large number of winter eggs. As no bronzing of the leaves has been observed by the fruitgrower he may well be of the opinion that there were few mites on the leaves and the result will seem to him to be anomalous.

Finally, of course, a really small number of mites will also produce a small number of winter eggs.

4. Competition

Apart from the Red Spider there are great number of other animals which feed on the leaves of fruit trees. This can be either by chewing or by sucking. In the first case we can assume that only the quantity of food available for the Red Spider is affected. In the second case there may be a considerable influence on the quality of the food but very little is known about that.

It has often been noticed that Aphids and Red Spider do not occur on the same trees in great quantities. Whether this might possibly be a case of food-competition has never been ascertained. It is generally supposed to be connected with winter spraying, tar-oil killing the Aphids and the natural enemies of Red Spider, while the mites themselves are not reduced in number. This question will not be discussed any further here as investigations are still in progress.

Fungi also attack the leaves and will probably reduce the quantity and quality of the food for the mites. Gilliat (1935b) draws special attention to the influence of scab (Venturia inaequalis (Cooke) Wint.) on apples but gives no further observations.

In August and September 1943 the leaves of many plumtrees were severely attacked by Puccinia pruni-spinosae Pers. The quality of food may have been reduced, certainly the quantity was reduced and there was premature shedding of the leaves as well, thus seriously reducing the period over which the mites could propagate.

Silverleaf (Stereum purpureum) attack on plums also affects the mites, as is shown in table 2.

Table 2. Influence of silverleaf attack on mite population on two trees of the variety Czar. Means of 100 leaves

date	silverleaf	mites	eggs
22 May '42	present	2.43 $\pm$ 0.48	0.01
	absent	30.30 $\pm$ 5.2	0.15
5 June '42	present	2.3	17.3
	absent	4.7	45.3

It is obvious that the mites do not thrive as well on trees attacked by silverleaf as on completely healthy trees. Needless to say the trees from which the leaves were taken were as similar as possible except for the silverleaf.

It is not known whether it is the structural changes in the leaves which impede the uptake of food (in the sick leaves the epidermis is slightly loosened from the parenchyma tissue) or whether toxic compounds from the fungus, which reach the leaves, change the quality of the food.

5. Egg production

One of the problems of the biology of the Fruit Tree Red Spider has always been the fact that the mite only occurs in destructive numbers in the well-kept orchards and not in the neglected ones. It has been generally assumed that the reason for this is the presence of predators under more natural circumstances, while the sprays applied in the well-kept orchards (specially the tar-oils) would kill the predators. The mites are known to be only little in-

fluenced by these sprays and relieved of the influence of the predators, they would then be able to multiply unchecked (Massee 1929, 1937).

It has not been shown quantitatively what the influence of the predators is but it seems very probable that the Anthocorids (*Anthocoris* spp., *Orius* spp.) and Coccinellids (*Scymnus minimus* Payk.) cannot be held responsible as they are mainly found where there is an abundance of mites. In neglected orchards they are comparatively rare (Kuenen 1947).

The predaceous Gamasid mites of the genus *Typhlodromus*, however, do occur in considerable numbers in the neglected orchards and may be responsible for the reduction of mites there, but this has not been proved yet.

In the mean time the possibility remains that other factors are (partly or wholly) responsible for the difference in mite population in the two types of orchards, and one of these is the egg production which, no doubt, is influenced by the quality and quantity of food which the mites consume. This is not the place to review the extensive litterature on this subject for which the reader is referred to textbooks and special reviews.

Experiments were made on a few specimens of Beauty of Boskoop, some in Zeelands Proeftuin, being well cared for, and others in a small garden, behind one of the houses nearby, where neither pruning or spraying was ever carried out. A slight manuring will have been in effect as the garden was used yearly for the growing of vegetables.

The technique for these experiments was slightly different from that used by Newcomer & Yothers (1929) for their study of this mite. The objection to their method is that the mites are confined to a small part of the leaf, where bronzing sets in very soon, thus changing too quickly the conditions under which the mites live.

My experiments were conducted in the following way. Around the stem of a leaf a ring of tanglefoot was made. All leaves in the neighbourhood were then taken away, so that the leaf was well isolated even if it was moved to and fro by the wind. All mites, eggs and other insects were then removed. From another tree on which there were a great number of teleiochrysalis, leaves were picked and from these leaves small bits were cut with scissors, each bit having one teleiochrysalis on it, mostly with one waiting male. This bit of leaf was then pasted onto the stem of the isolated leaf. In this way a number of leaves was inoculated at the same time, both on the well-kept and on the neglected trees. Every day, following this manipulation, the leaves were inspected, first to see whether the female, emerging from the teleiochrysalis had got onto the leaf safely, and after that to count the number of eggs produced and to check the presence of the female. Frequently the females disappeared from the leaves before they had produced any number of eggs, and generally this was through rain washing them off. The results are tabulated below (table 3).

Table 3. Egg-production on trees from well-kept orchards and from neglected garden.

	3—14 July '43			6—20 July '43			22 Aug.-4 Sept.'43			7—19 July '44		
	♀♀	eggs	mean per ♀	♀♀	eggs	mean per ♀	♀♀	eggs	mean per ♀	♀♀	eggs	mean per ♀
Well-kept trees	7	14		4	20		5	13		8	20	
		17			28			20			10	
		10			16			19			12	
		14			17	20.2		4			15	
		15				±2.7		21	15.4		7	
		13							±3.2		35	
		16	14.2								19	
			±1.0								29	18.4
												±3.4
Neglected trees	3	5		6	13		4	7		4	12	
		8			6			3			9	
		2	5.0		4			11			5	
			±1.7		6			3	7.0		8	8.2
					4				±1.9			±1.4
					9	7.0						
						±1.4						
	difference = 9.2 ± 1.9			difference = 13.2 ± 3.0			difference = 9.4 ± 3.7			difference = 10.2 ± 3.7		

Mean of all countings:
well-kept trees: 24 ♀♀ and 404 eggs = 16.8 ± 1.4
neglected trees: 17 ♀♀ and 114 eggs = 6.7 ± 0.8
difference = 10.1 ± 1.6

The results show that, in spite of the comparatively few inoculations which were successful, they are sufficiently reliable. It should be remembered that the females which produced these eggs have lived all their life since hatching, on the same tree, and only after their mature period had started did the difference in food begin. Had they lived under different conditions all their life the difference in egg-production might have been even greater.

But even the difference which is found here, that the egg-production is 2½ times as great in one case as in the other, is of great significance to the mite, as there are 4 or 5 generations. If the initial population in the two cases is the same, and this factor acts alone, and constantly throughout the reproductive season; the final populations differ in a ratio of $1 : 2.5^3$ in the 4th and $1 : 2.5^4$ in the 5th generation (which is 1 : 15.6 and 1 : 39 respectively). If we include the winter egg-production, the ratio is $1 : 2.5^4$ and $1 : 2.5^5$ (or 1 : 39 and 1 : 98) with 4 and 5 generations.

The difference in egg-production alone, then, can be held responsible for the difference of development of the Red Spider in neglected and well-kept orchards.

It does not follow from this what the causal factor in the treatment of the trees is. Fertilizers seem the most probable, but probably sprays have a great influence too. Only an extensive further investigation can yield reliable results here.

Preliminary determinations of N_2-content of a few leaves were made for me at the laboratory of Mr van der Have at Kapelle, by Mr A. Hendriksen, for whose help I am very grateful.

Leaves were collected of the variety Court Pendu from a well-kept and from a neglected orchard. The results are summarized in the following table (table 4).

Table 4. Nitrogen-content of leaves from different localities.

	size in cm^2	dry weight	N_2-contents	N_2/area	N_2/weight
Neglected					
sample no. 1	75.1	0.5000 g	9.344 mg	0.124	1.93 %
2	71.0	0.4585	8.462	0.119	1.88
3	75.6	0.5000	9.350	0.124	1.92
4	81.4	0.5660	10.706	0.131	1.92
				0.125	1.91 %
Well-kept					
sample no. 1	75.7	0.7705	18.720	0.247	2.43
2	77.9	0.7800	17.460	0.224	2.27
3	80.4	0.8400	20.471	0.255	2.47
4	112.4	1.1655	29.851	0.266	2,59
				0.248	2.44 %

The great difference is obvious. Further investigations have been planned, but have not yet been carried out.

6. Variety and rootstock

It is a well known fact that not only different species of trees but also the varieties of one species are attacked in different degrees by the Fruit Tree Red Spider.

Some difficulties arise when we try to express this difference in susceptability more exactly. As a rule it is judged by the extent to which trees show bronzing under the influence of the attack. It is quite probable, however, that there is no direct relation between the number of mites and the intensity of discoloration, because one variety may show symptoms at a much lower density of mites than the other. Besides the condition under which the tree grows may influence the symptoms to a large degree.

Garman (1923) was the first to direct attention to this fact. He reports that the varieties Wealthy and Spy show bronzing when there are 12—33 mites per leaf, while other varieties did not show discoloration before the population was 55—133 mites per leaf. It may be doubted, however, whether these data are reliable,

as Garman apparently did not realise that the number of mites quickly diminishes as soon as bronzing begins.

Differences in numbers of mites can only be determined by countings on trees which differ only in variety, but are otherwise equal. As the rate of change in the populations is very quick, such a counting must not take more than one or at the most two days.

In the summer of 1943 two such countings were made on Cox's Oranje Pippin and Beauty of Boskoop to assess the difference in population as affected by the variety and also by the rootstock.

Table 5. Numbers of mites and eggs with mean square error) on two varieties and three rootstocks. Mean per leaf from 100 leaves.

Var.	Rootstock	8 May 1943		24 Sept. 1943		mean mites 24.IX
		mites	eggs	mites	eggs	
Cox	IX	2.89 ± 0.58	0	7.12 ± 0.88	2.50 ± 0.41	
	IV	2.45 ± 0.43	0	2.97 ± 0.57	0.95 ± 0.23	
	XVI	2.38 ± 0.45	0	6.41 ± 0.70	1.63 ± 0.25	**Cox:** 5.50
Boskoop	IX	2.66 ± 0.45	0	3.94 ± 0.87	0.62 ± 0.16	
	IV	1.97 ± 0.59	0	0.66 ± 0.13	0.78 ± 0.16	
	XVI	1.95 ± 0.30	0	1.44 ± 0.27	0.84 ± 0.15	**Boskoop:** 2.01

While we see from the table (table 5) that all trees have about the same density of population in the beginning of the year, the differences at the end are considerable. After a spray of oil + d.n.c. in March the normal spraying programme was performed on these trees including 3 sprays of lime-sulphur during the summer. The whole block was treated simultaneously and as far as possible homogeneously.

If we reckon with the size of the leaf the difference is even greater as the Cox has smaller leaves than the Boskoop, on which it harbours a larger population. The results of the measurement of the leaves are tabulated below (table 6).

Table 6. Size of leaves, mean of 25 measurements, in cm²

Var.		8 May	mean	24 Sept.	mean
Cox	IX	12.8		20.3	
	IV	11.4		20.7	
	XVI	19.5	14.5	22.9	21.3
Boskoop	IX	16.9		30.5	
	IV	25.0		34.8	
	XVI	29.9	23.9	35.2	33.5
Cox: Boskoop = 1 : 1.64				1 : 1.57	

The leaves were measured by drawing the contour of 25 leaves

per sample on paper and measuring these surfaces with a planimeter.

Table 5 further shows us that the rootstock has a marked influence also. In both cases E.M. type IV gives the smallest population density. Presently it will be shown that the rootstock of plums too affects the numbers of mites.

Differences as those mentioned by Garman (l.c.) were noticed during various experiments. In 1942 the varieties Grimes Golden Pippin and Perzikrode Zomerappel both showed bronzing of the leaves, which appeared on the Grimes when there were about 45 mites per leaf and on the Perzikappel at 80 to 120 mites per leaf. As the leaves of the Perzikappel are about $1\frac{1}{4}$ times as large, the population density was about $1\frac{1}{2}$—2 times as large.

On a plot of plums at Wilhelminadorp countings of the numbers of mites were made in 1941. There are 13 rows running north and south, each row consisting of 12 trees of the same variety. Every variety is worked on four rootstocks, the three rows of the same rootstock running east-west. The only exception is the variety Czar which is incompatible with the rootstock Brussels, and has therefore been worked on Tonneboer. Of every three trees which are thus the same in variety and rootstock one tree was used and 25 leaves were taken for the counts of each tree. Of each variety therefore 100 leaves and of each rootstock 325 leaves. The results are given below (table 7).

Table 7.

	Czar	Dubb. Boerenwitte	Purple Pershore	Doyenné	R. Cl. d'Althann	R. Cl. d'Hoefer	Gele Heerenpruim	R. Cl. de Brahy	Ontario	Monarch	Kirkes	R. Cl. Verte	C. Golden Drop	Total (excl. Czar)	Total per tree (25 leaves)
Brussels	(1715)	147	781	1157	380	49	414	248	157	994	830	243	320	5720	477 ± 106
C. Mussel	1392	1680	1312	1117	598	66	777	335	1044	2111	857	535	368	10800	900 ± 166
Myrab. B.	1177	1009	1537	839	502	626	361	205	426	1471	1197	766	465	9404	784 ± 127
Kroosjespr.	1688	1395	909	939	290	321	785	241	510	1018	636	491	335	7870	656 ± 103
per var. (100 leaves)	5972	4231	4539	4052	1770	1062	2337	1029	2137	5594	3520	2035	1488		
per leaf mean from 100 leaves	59.7 ± 3.8	42.3 ± 4.3	45.4 ± 3.5	40.5 ± 2.8	17.7 ± 1.4	10.6 ± 1.6	23.4 ± 2.0	10.3 ± 1.2	21.4 ± 2.1	55.9 ± 4.5	35.2 ± 2.6	20.3 ± 1.6	14.9 ± 1.3		

The attack on the different varieties decreases in the following order: Czar, Monarch, Purple Pershore, Dubbele Boerenwitte, Doyenné, Kirkes, Ontario, R.Cl. Verte, R.Cl. d'Althann, C. Golden Drop, R.Cl. d'Hoefer, R.Cl. de Brahy.

The counting was carried out late in the season (11 and 13 September '41) and some bronzing could be seen. This may have confused the result to some extent and it should therefore be remembered that these numbers may not have general validity but only give the difference in population at that particular moment.

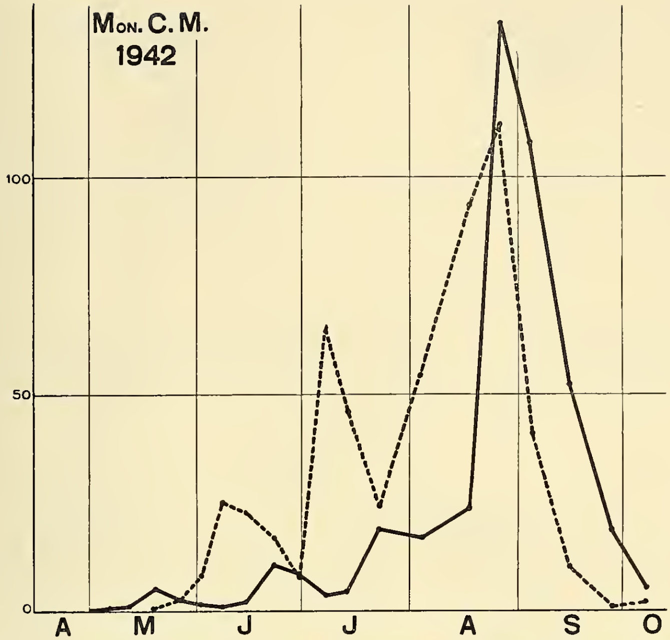

Fig. 4. Idem as fig. 2. Mon. C. M. : plum var. Monarch, rootstock Common Mussel.

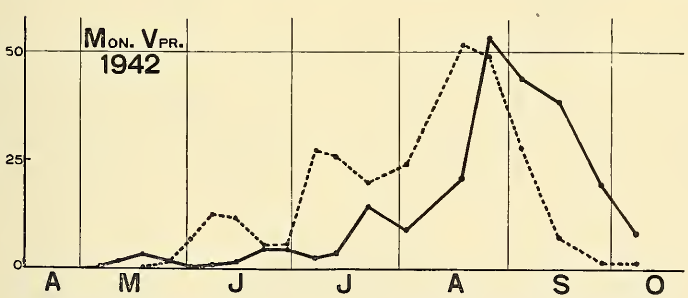

Fig. 5. Idem as fig. 2. Mon. Vpr. : var. Monarch, rootstock Brussels.

The results were such that it seemed of interest to continue the countings of mites throughout the year on a restricted number of trees. This was done on the varieties Monarch, Gele Heerenpruim and Reine Claude d'Hoefer, each on the rootstocks Common Mussel and Brussels.

The results are given in the graphs (figs. 4—15). In the graphs for 1942 there is an obvious difference between the varieties. This difference increases with each generation. The absence of a 5th generation on the Monarch is due to overcrowding in the 4th which

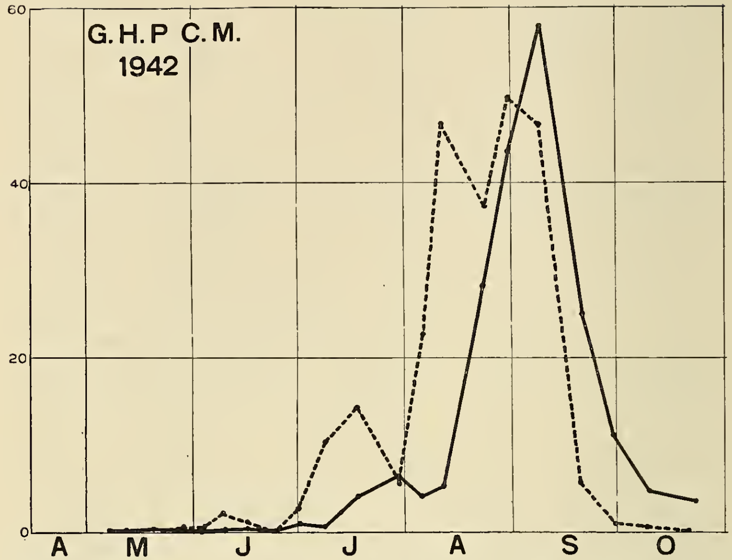

Fig. 6. Idem as fig. 2. G. H. P. C. M. : var. Gele Heerenpruim, rootstock Common Mussel.

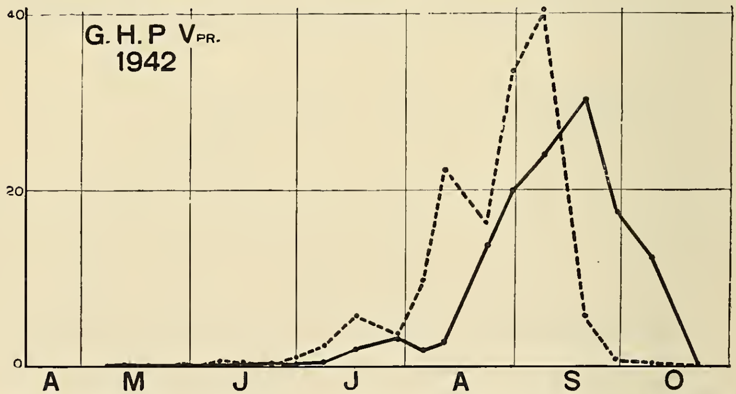

Fig. 7. Idem as fig. G. H. P. Vpr. : var. Gele Heerenpruim, rootstock Brussels.

gave rise to bronzing of the leaves and subsequent reduction of the population.

In 1943 only few eggs hatched on the Monarch. This may to some extent be due to different numbers of eggs being killed during the winter but it is certainly largely due to the fact that the 4th generation mites did not produce as many eggs as the 5th generation mites on the other trees did, a phenomenom which can be observed regularly. In spite of this small number of mites in the

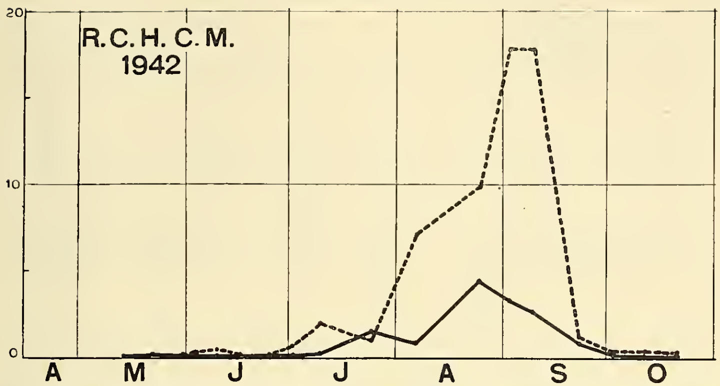

Fig. 8. Idem as fig. 2. R. C. H. C. M.: var. Reine Claude d'Hoefer, rootstock Common Mussel

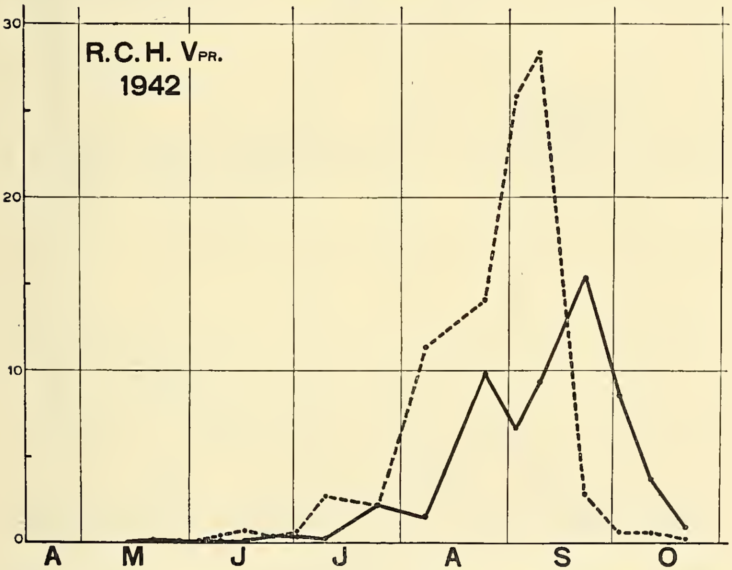

Fig. 9. Idem as fig. 2. R. C. H. Vpr.: var. Reine Claude d'Hoefer, rootstock Brussels.

beginning of the year the normal relation is restored during the summer, Monarch having the largest population. Therefore some factor acting during the summer must regulate the relative numbers on the different varieties.

The differences between the rootstocks are also apparent, though not as clear as between the varieties. This was partly caused by the accidental distribution of the predators, the influence of which

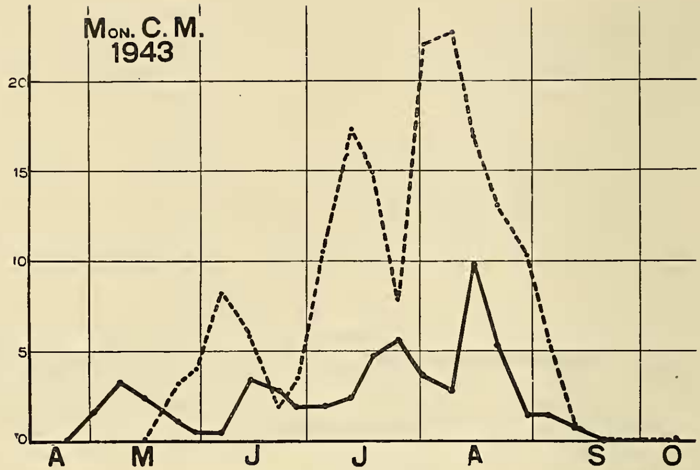

Fig. 10. See fig. 4.

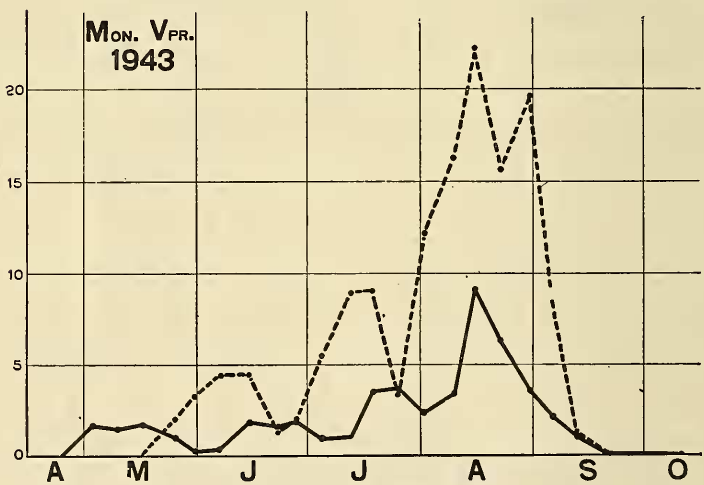

Fig. 11. See fig. 5.

shall not be discussed here (see Kuenen, 1947).

There are few indications in the literature as to what might be the cause of the difference in attack on different varieties. Garman (1923) thinks that thin-leaved varieties show bronzing sooner than thick-leaved ones.

Anatomical study of the leaf showed us that there was a certain correlation between the thickness of the cuticula and the intensity of the red-spider attack (table 8).

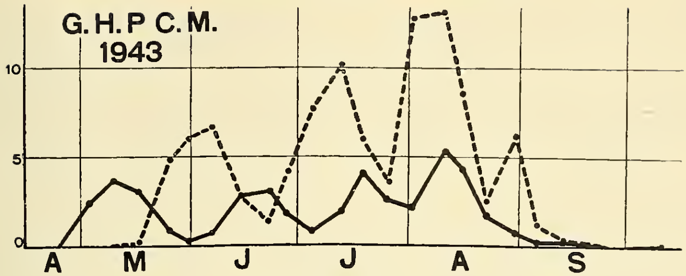

Fig. 12. See fig. 6.

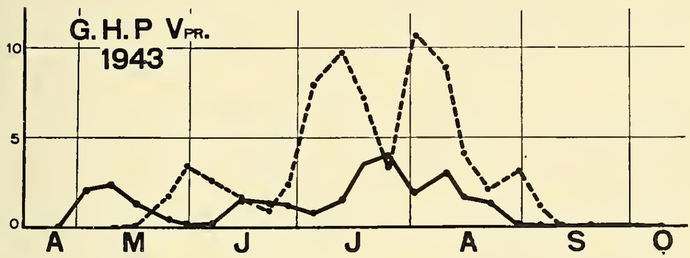

Fig. 13. See fig. 7.

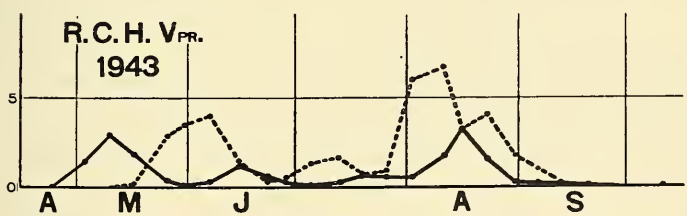

Fig. 14. See fig. 8.

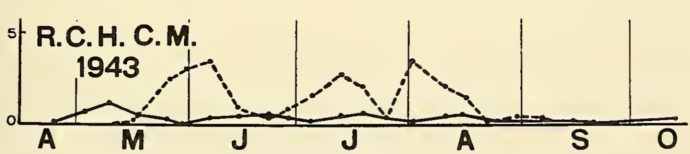

Fig. 15. See fig. 9.

Table 8. Thickness of cuticula + outer wall of epidermis in μ. Means of 10 measurements (by H. J. Hueck)

	upper cuticula		lower cuticula	
	V. pr.	C. M.	V. pr.	C. M.
Mon.	2.7	2.9	1.4	1.7
G. H. P.	4.1	3.9	2.2	1.8
R. C. H.	4.2	3.9	2.9	2.7

It is clear that the thicker the cuticula + outer epidermis wall, the smaller the red spider population.

If we carry out similar measurements on other trees we get the following approximations (table 9).

Table 9. Thickness of the cuticula in μ of a few varieties of apple and pear.

Apple	upper cuticula	lower cuticula	Pear	upper cuticula	lower cuticula
Beauty of Boskoop	1—1½	1	Triomphe	3	3—4
			Précoce	1½	4
Cox's Or. P.	1	1	Clapp's	3—4	4
Allington P.	1	½—1	B. Hardy	2	3—4
Grimes Golden Pippin	½—1	½	B. Louise	2—3	4

It is obvious that the cuticula of the pear being much thicker than that of the apple, the latter is much more attacked by mites than the pear. Of the pears the cuticula is the thinnest in Précoce which is the variety of pear most liable to Red Spider attack. A comparison between apple and pear on the one hand and plum on the other is not possible from these data as Hueck measured the cuticula together with the outer wall of the epidermis.

Now if the cuticula is of such importance for the accessability of the food for this mite this may also be the explanation for the behaviour of the mite in warm weather, previously described (p. 84). The cuticula being of a waxlike nature, its consistency will vary with the temperature, becoming softer as the temperature rises. The thicker cuticula on the upper surface of the leaf will be easier to penetrate in warm weather and this may well be the reason why the mites only migrate there if the temperature is above a certain level.

The question of the influence of food on the epidemiology of insects is certainly complicated. The data which we possess concerning the relation between the food and abundancy of the Fruit Tree Red Spider are doubtlessly very sparse. It seems worth while, however, to compile the results obtained in Holland during the war for the benefit of those who cannot read the Dutch language. Work

is still in progress on those points where it is most obvious that further data are wanted.

7. Summary

Certain aspects of the influence of food on the epidemiology of the Fruit Tree Red Spider Mite have been investigated as part of a general study on its biology and control.

The damage done to the leaf consists in perforating the epidermis and ingestion of the contents of the parenchyma cells. Only feeding at the upper surface of the leaf gives rise to the well known bronzing, the cells of the sponge parenchyma not showing any discoloration when punctured. The mites live on the lower surface of the leaf and only come to the upper surface when the temperature is high. This may be because the upper cuticula is thicker and can only be pierced easily when softened through higher temperature. Consequently there may be a large population present for considerable time without the bronzing of the leaves becoming apparent, while a few days of hot weather, bringing the mites to the upper surface, will result in the sudden appearence of extensive discoloration.

A study of the population dynamics showed that as soon as bronzing of the leaves occurs the mites migrate prematurely from the leaf to the branches and deposit only few winter eggs. Consequently after a heavy infestation we find few winter eggs, while a population of medium density does not overeat its foodsupply and produces a very large number of winter eggs.

Trees attacked by silverleaf or other fungus diseases, and possibly also those on which Aphids feed in large numbers have a much smaller Red Spider population than healthy trees.

Egg production is much greater on trees in good condition than in neglected orchards. This difference may explain the much more vigorous development of the mite in the well kept orchard though other factors cannot, for the present, be ruled out.

The size of the population is influenced by the variety of tree on which it occurs and also by the rootstock on which the tree is grafted, though to a lesser degree. There is a correlation between the thickness of the cuticula and the susceptibility to Red Spider, the thickest cuticula going with the highest resistance.

The investigations are being continued.

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